ICES CM 2004/R:42

First Test Results from the New Norwegian Lidar for Monitoring of Marine Resources.

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Following promising lidar test flights in 2002, Institute of Marine Research (IMR), Bergen in cooperation with NTNU University, Trondheim started the process of designing and building a new lidar to be ready by summer 2004. It is based on the National Oceanographic and Atmospheric Administration (NOAA) lidar used during the 2002 test flights. The paper presents the first results obtained during the mackerel (*Scomber scombrus*) survey in July 2004. This is an annual survey using two commercial vessels to map the distribution and density of mackerel in the Norwegian Sea during summer feeding using sonar and trawl. The lidar flights cover the same tracks as the vessels and the results are compared. An intercalibration routine between lidar and sonar was tested. The idea was to cover a school of fish observed on the vessel sonar by numerous lidar flights. Finally, the plans for mounting the lidar onboard R/V “G.O. Sars” is presented.

Keywords: lidar, mackerel, sonar, trawl

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INTRODUCTION

In July 2002, Institute of Marine Research (IMR), Bergen carried out 11 flights with the NOAA lidar (Churnside et al. 2001a) to test its ability as a survey tool for pelagic fish. The results from these tests shoved that the lidar was able to observe fish schools in the upper 35 meters during the summer season in the Norwegian Sea (Tenningen et al. 2003). A study using sonar (Godø et al. 2004) has shown that the majority (65%) of the mackerel schools are in the upper 40 meters of the water column during this period.

Following the 2002 survey, IMR started collaboration with the Norwegian University of Science and Technology (NTNU), Trondheim to design and build a new lidar. The design of the first version was made in close co-operation with the National Oceanographic and Atmospheric Administration (NOAA), USA. The optical design is almost identical to this lidar, while the data-acquisition system is slightly changed for better dynamic area without the use of a logarithmic amplifier. In the beginning of July 2004, the lidar was ready for lab testing and by mid July the system was ready for the first test flights.

Three survey flights, each of about 8.5 hours duration, were carried out onboard the aircraft “Arktika” from the Knipovich Polar Institute of Marine Fisheries and Oceanography (PINRO), Russia in the period from 20.07-25.07.2004.

In this paper the equipment will be described and some preliminary results will be shown. In addition, the plans for mounting the equipment onboard the R/V “G.O. Sars” will be presented.

MATERIALS AND METHODS

The lidar was based on the well-tested NOAA lidar (Churnside et al. 2001a) in order to build a system within limited time and on a relatively small budget. The lidar components are shown in figure 1. This first-version is built without scanning capabilities and is operating at a single frequency. It is slightly forward tilted (15 degrees) to reduce specular reflections from the sea surface. Onboard the aircraft the 27V DC power is converted to 220V AC through a 3kW sinus DC/AC converter as most of the components are designed to operate at this voltage.

The laser is a Neodymium-doped Yttrium Aluminum Garnet (Nd:YAG) with a Q-switch that is opened after the crystal is fully charged, so that all the energy is extracted in a 12 nsec pulse (see Churnside et al. 2001b for more details). The light is converted from an infrared wavelength (1064 nm) to visible green (532 nm) through a non-linear optical crystal. The output energy in each pulse is 130 mJ and the pulse repetition rate is 30 Hz. The linearly polarized beam is diverged (18 mrad) through a negative lens in front of the laser producing a disk on the surface having a diameter of approximately 5 m. At 180 knots a new pulse is produced every 3 meter giving an overlap of 2 meters from one pulse to the next.

The receiver optics are comprised of a 17 cm diameter refracting telescope with a polarizing filter in front. The filter was adjusted to only allow for cross-polarized light to pass. This has been found to give the best contrast between fish, water, and other small scatterers in the sea (Churnside et al. 1997). The beam is focused by a primary and a secondary lens and a band-pass filter only transmitting light in a 1 nm band around the laser wavelength reduces the impact of other light sources such as direct sunlight and specular reflections from the sea surface. The returned light is then amplified and converted to an electrical signal through a photomultiplier tube (pmt) and digitized at 400 MHz with 12 bits resolution. This gives better receiver dynamics than the 8 bits used by NOAA (Churnside et al. 2001a) so that a logarithmic amplifier is not needed.

The voltage signal, gps time, and gps position are stored in the computer. The real-time display shows a line plot of the return signal as a function of time for each shot. A lidarogram display similar to echograms used in acoustics is also available.

The three flights covered areas in the Norwegian Sea ranging from 62°45N to 70°15N and 04°30W to 10°00E (see figure 2). As in 2002 and in 2003, there were two commercial vessels hired by IMR covering the same areas using sonar and trawl to find the distribution of mackerel (see Godø et al. 2004 and Tenningen et al. 2003a).

To better understand the relationship between lidar and acoustics return from schools of fish, calibration flights were planned. The idea was to cover schools observed on sonar by several flights. Then the return can be compared from the same school and the equipment calibrated.

RESULTS

The lidar was installed onboard the PINRO aircraft “Arktika” on July 19th 2004 (see figures 3 and 4). There were some small problems getting the equipment to function properly on the first flight covering the southern part of the survey area, but these were solved onboard.

Flight number two covered the middle part of the survey area and there were some good backscattering recordings between 67°N and 68°N. See lidarogram in figure 5. The lidarogram shows schools believed to be mackerel within a plankton layer. The curves for four single shots are plotted in the same figure. The first curve is from an area containing no fish, while the three other shots all contain fish indicated by the increased return signal. The plots were made using the PINRO lidar post-processing program.

Only a limited amount of the data have been processed in time for this paper so an overall distribution map cannot be given. When post-processing of the lidar data is finished, they will be compared to the trawl and sonar data collected by the two vessels.

The intercalibration between acoustics and lidar also has yet to be completely analyzed. The two commercial trawlers M/S “Endre Dyrøy” and M/S “Libas” were contacted when in the same area, but no significant mackerel schools were found for calibration between lidar and acoustics.

DISCUSSION

The calibration between the airborne lidar and the sonars onboard the vessels seems to be a more difficult task than first expected. The aircraft has to be close to the vessels and at the same time there has to be mackerel present. When the flying hours are limited (25 hours in 2004) this is hard to combine with the scheduled area coverage. For better calibration with acoustics, the lidar will be placed onboard R/V "G.O. Sars" along with the echosounders and sonar in October 2004 during a mackerel survey. As the lidar is designed for use onboard aircrafts flying at an altitude of 300 meters, a few adjustments have to be made. First, the laser output must be weakened for safety purposes and the beam divergence must be widened because of the reduced altitude. A container has to be made to protect the laser and receiver against sea spray and rain. Also the lidar has to be mounted at a place that is both safe and where the effects of the ship waves are minimum. White wave caps and foam limits the depth penetration drastically.

In August 2004 the lidar was brought onboard R/V "G.O. Sars" to look at different mounting possibilities. It was found that the initial position behind the instrument room (see figure 6) was far from ideal as the white-capped waves made by the ship were in the lidar field of view at speeds exceeding seven knots. The most practical placement of the lidar was found to be on top of the bridge pointing at a 15-degree angle forward and to the side of the ship. Here the wave problem is avoided and there is easy access to power and the onboard computer network.

Depending on sufficient funding, a new version of the lidar will be built having both scanning capabilities and an additional receiver collecting light co-polarized with the laser. Scanning will allow for 3-dimensional data collection and the additional receiver channel will give the possibility of distinguishing between different species (Tenningen et al. 2003b).

ACKNOWLEDGEMENT

Thanks to the PINRO crew and scientists onboard the aircraft “Arktika” we had three successful lidar flights.

REFERENCES

Churnside, J.H., Wilson, J.J., and Tatarskii, V.V. 1997. Lidar profiles of fish schools. Applied Optics, 36:6011-6020.

Churnside, J.H., Wilson, J.J., and Tatarskii, V.V. 2001a. Airborne lidar for fisheries application. Optical Engineering, 40:406-414.

Churnside, J.H., Sawada, K., and Okumura, T. 2001b. A comparison of airborne lidar and echo sounder performance in fisheries. J.Marine Acoust. Soc. Jpn. Vol. 28 No.3.

Godø, O.R., Hjellvik, V., Iversen, S.A., Slotte, A., Tenningen, E., and Torkelsen, T. 2004. Behaviour of mackerel schools during summer feeding migration in the Norwegian Sea, as observed from fishing vessel sonars. ICES Journal of Marine Science, 00: 000-000. Article in press.

Tenningen, E., Godø, O.R., Iversen, S., Slotte, A., Hjellvik, V., and Torkelsen, T. 2003a. Comparison of Northeast Atlantic mackerel (*Scomber scombrus*) distribution patterns in the Norwegian Sea using lidar, sonar and trawl. ICES CM 2003/V:04. 16 pp.

Tenningen, E., Churnside, J.H., and Slotte, A. 2003b. Lidar TS measurements on Northeast Atlantic mackerel (Scomber scombrus). ICES CM 2003/V:05. 11 pp.

FIGURES

Figure 1. The lidar consists of the optical system containing laser, receiver optics, and a photomultiplier tube, laser cooling and power supply, a DC/AC converter for use onboard aircrafts, the data acquisition system, and a industry PC for operating the system and storing of data.

Figure 2. The flight tracks.

Figure 3. Lidar installed onboard Russian aircraft “Arktika”.

Figure 4. PINRO aircraft “Arktika”.

Figure 5. Lidarogram of a few schools believed to be mackerel. The curves are line plots of the return signal from water with plankton layer, the first containing no fish and the three others containing fish schools within the plankton layer. The data are processed using the PINRO lidar post-processing program.

Figure 6. The lidar mounted onboard R/V “G.O. Sars”.

Figure 1.

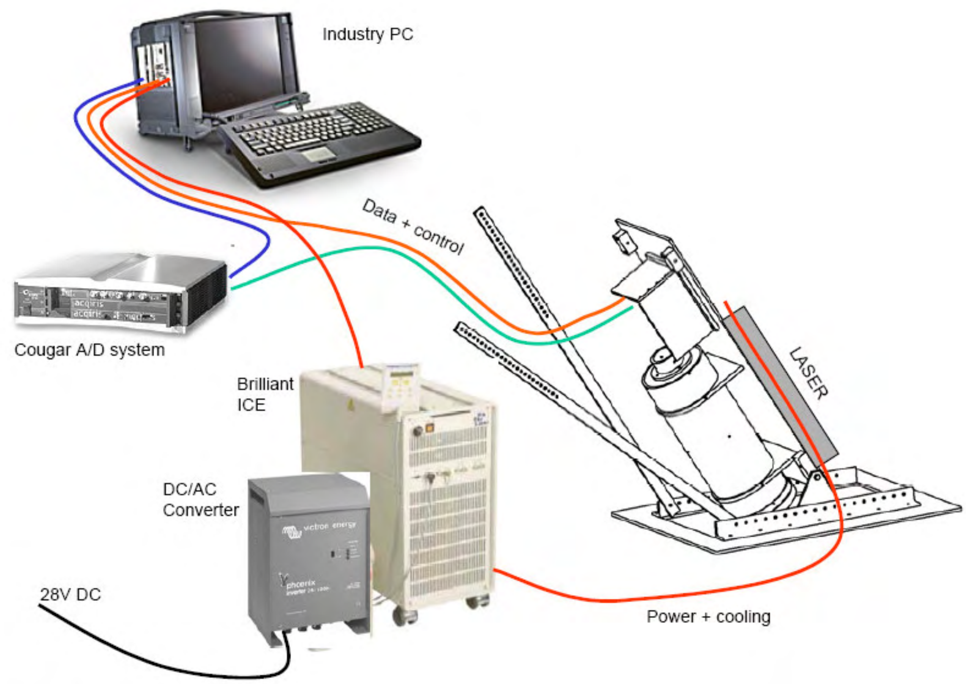


Figure 2.

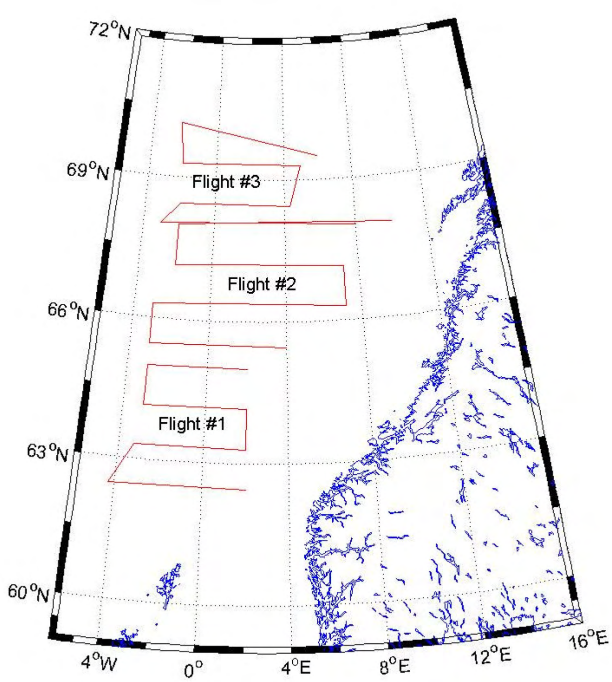


Figure 3.

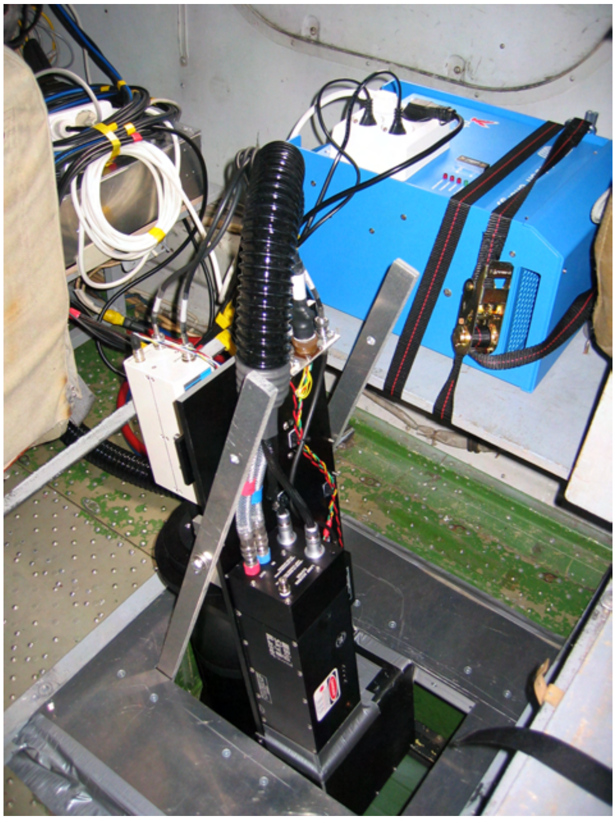
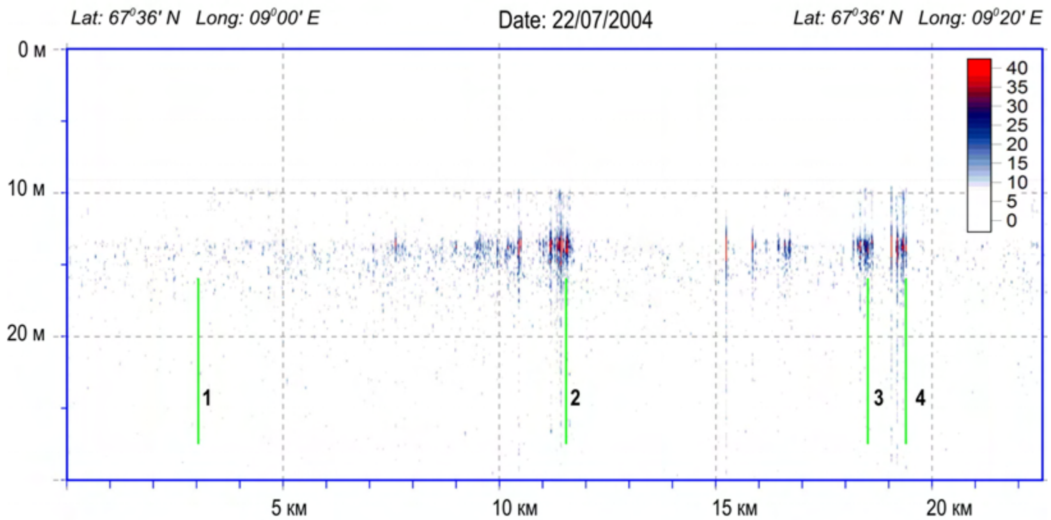


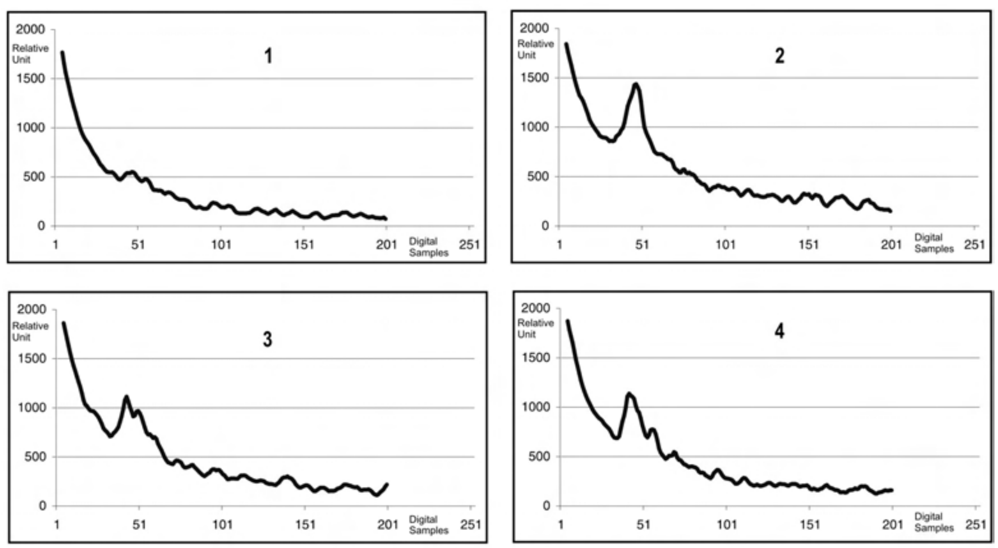
Figure 4.

Figure 5.

LIDARograme of the postprocessing data



Curves



RAW data by IMR
Postprocessing of the LIDAR data by PINRO

Figure 6.